HC-SCR of NOx for light duty diesel vehicles

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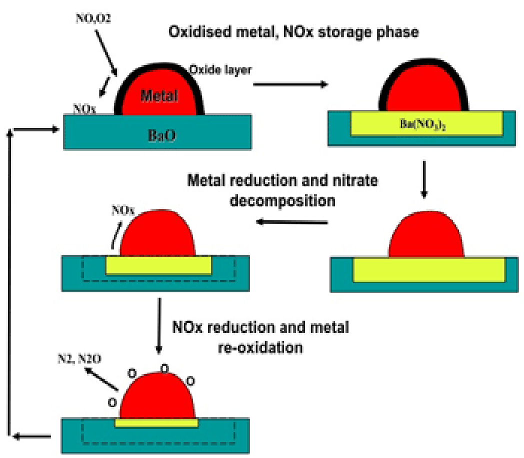
CSIR-NCL

Strategies for diesel car aftertreatment

NOx Storage Reduction (NSR)

$2NO + 2O_2 \xrightarrow{Pt} 2NO_2 + O_2 \xrightarrow{Ba} Ba(NO_3)_2$

$Ba(NO_3)_2 + HC + H_2 + CO \rightarrow CO_2 + H_2O + N_2$



- 👍 Developed technology
- 👍 Optimised catalyst composition

- 👎 Need expensive Pt for NO ⇨ NO_2
- 👎 Permanent deactivation of storage component (Ba) even with traces of S
- 👎 Needs to replace catalyst after complete formation of $BaSO_4$

Selective Catalytic Reduction (SCR)

NH_3 (Urea) - SCR

$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$

V_2O_5-WO_3/TiO_2, Zeolite based

- 👍 Developed technology
- 👍 Suitable for heavy duty vehicles or stationary sources

- 👎 Need to carry urea tank on board
- 👎 Not suitable for small vehicles due to space constraints

HC-SCR

$2CO + 2NO \rightarrow 2CO_2 + N_2$

$HC + NO \rightarrow CO_2 + H_2O + N_2$

$2H_2 + 2NO \rightarrow 2H_2O + N_2$

- 👍 Unburnt hydrocarbon or small fuel penalty can be used for NOx reduction
- 👍 Specially suitable for small vehicles
- 👍 No need to carry additional tank for reductant

- 👎 Ready technology not available

Opportunity for development

Initial work carried out by NCL

HC-SCR of NOx under lean conditions

Advantages compared to Urea-SCR

- No need to carry additional urea tank
- No problem of NH_3 slip
- Use of un-burnt HC for reduction of NOx or slight additional fuel penalty
- Preferred for passenger cars and small carrier vehicles

Work Carried Out So Far ……

2 wt% Ag/Al_2O_3 is used as benchmark catalyst for HC-SCR

- ↑ Maximum NOx reduction activity
- ↑ Maximum selectivity for N_2

- ↓ Poor activity at lower (<200 ºC) and higher temperature (>400 ºC)
- ↓ Low sulfur tolerance
- ↓ Moderate activity in presence of water

Activity can be improved by

- ❖ Modification of support or
- ❖ Addition of second metal

Catalysts compositions developed and evaluated at CSIR-NCL

$Ag-Au/Al_2O_3$ catalysts

Test Procedure

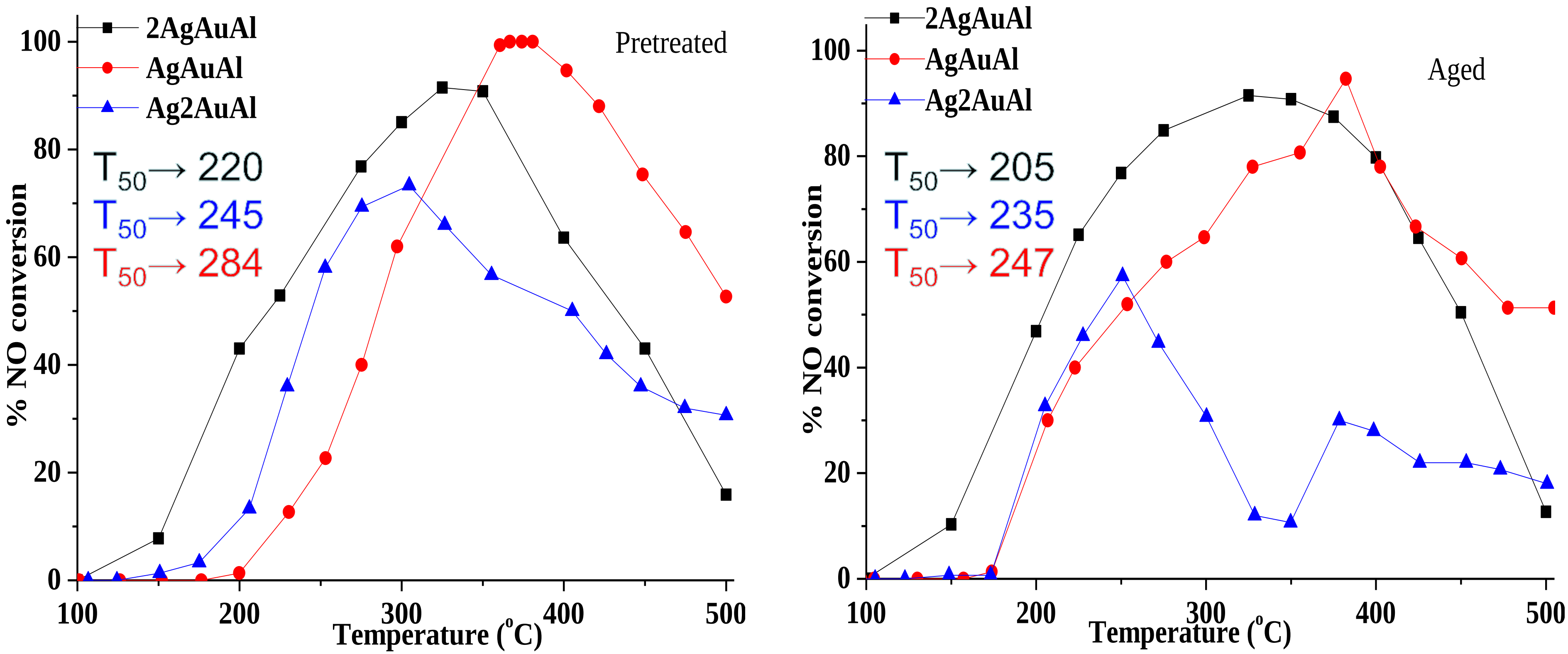
1. Heat the catalyst powder in hydrogen at 250 ºC for 12 h
2. Cool to room temperature
3. Pass simulated exhaust gas composition on catalyst bed from 80-500 ºC @ heating rate of 2 ºC/min and monitor the conversion of NO to N_2 (termed as fresh catalyst)
4. Pass the exhaust feed on catalyst bed at 800 ºC for 8 h
5. Cool to 80 ºC
6. Again pass simulated exhaust gas composition on catalyst bed from 80-500 ºC @ heating rate of 2 ºC/min and monitor the conversion of NO to N_2 (termed as aged catalyst)

Simulated exhaust gas composition:

300 ppm NO, 300 ppm CO, 300 ppm C_3H_6, 2000 ppm H_2, 100 ppm $C_{10}H_{22}$, 10% CO_2, 10% O_2, 5% H_2O, He balance.

GHSV = 50,000 $mL.g^{-1}.h^{-1}$

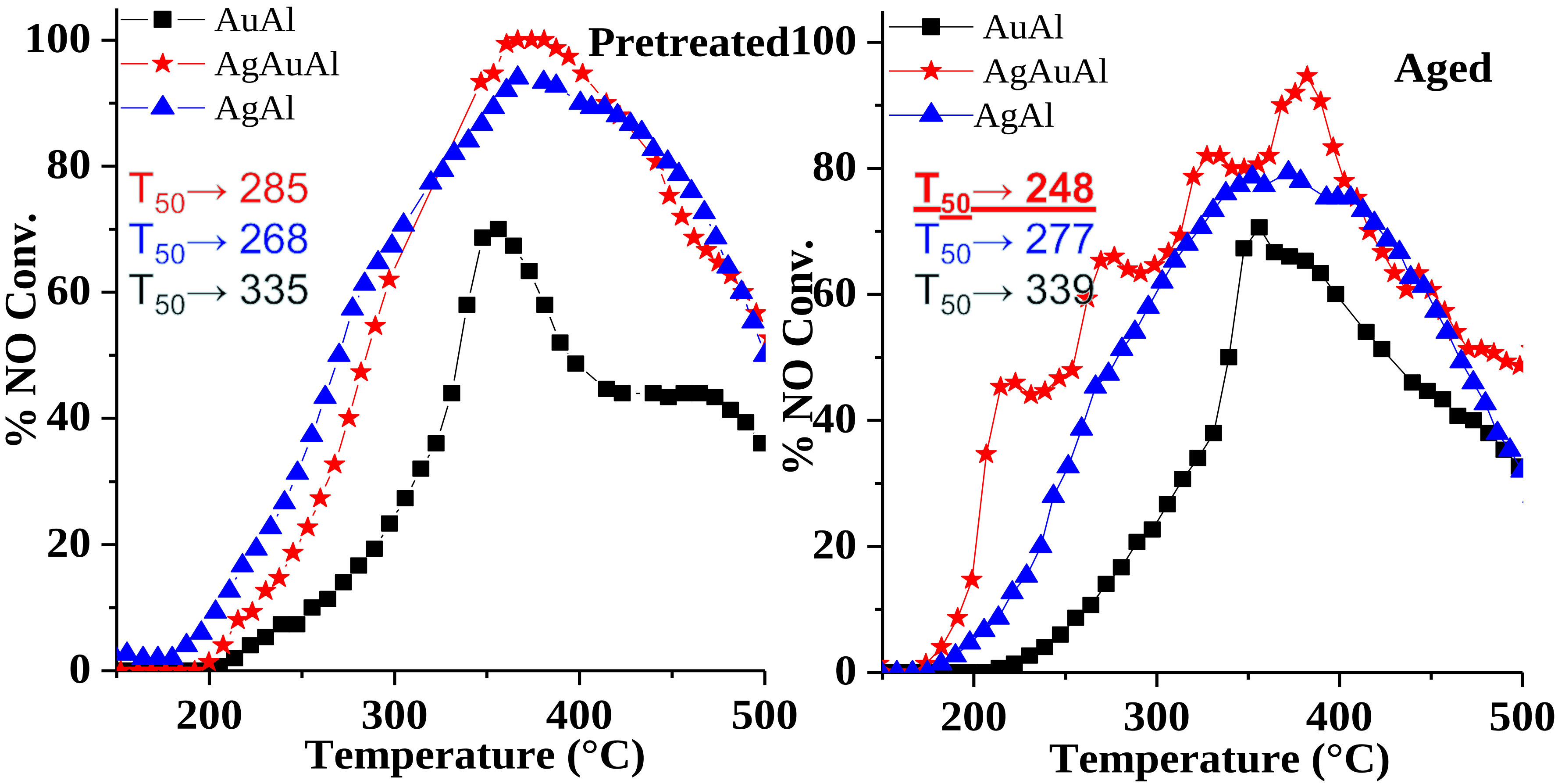
SCR activity of different AgAu catalysts



Reaction feed:- 300 ppm NO, 300 ppm CO, 300 ppm C_3H_6, 2000 ppm H_2, 100 ppm $C_{10}H_{22}$, 10% CO_2, 10% O_2, 5% H_2O, He balance, GHSV=50,000 $mL.g^{-1}.h^{-1}$.

Promising NO conversion to N_2 in a wide temperature range of 200-500 ºC
Catalyst activity improved after ageing – treating under simulated exhaust composition at high temperature

DeNO$_x$ activity comparison of AgAuAl with AgAl and AuAl



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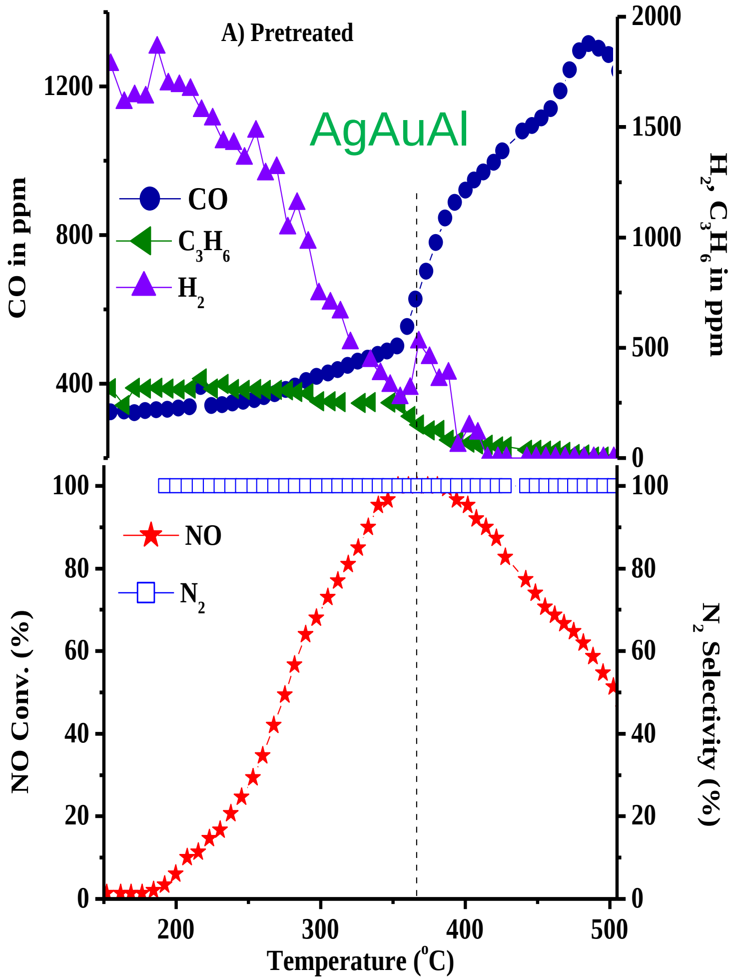
After aging activity of AgAuAl increased
Almost 50% NO conversion even at 250 ºC
Activity of bimetallic Ag-Au/Al_2O_3 is better than only Ag/Al_2O_3 or Au/Al_2O_3

Correlation of deNO$_x$ activity with measurement of CO, H_2 & C_3H_6



- NOx conversion to only N_2
- No N_2O formation
- Under reaction condition reforming takes place forming hydrogen in situ
- In situ formed hydrogen helps for low temperature reduction of NO
- Significant NO reduction even at high temperature (500 ºC)

Reaction feed:- 300 ppm NO, 300 ppm CO, 300 ppm C_3H_6, 2000 ppm H_2, 100 ppm $C_{10}H_{22}$, 10% CO_2, 10% O_2, 5% H_2O, He balance, GHSV=50,000 mL.g^{-1}.h^{-1}.

High DeNOx activity at high temperature

Summary

- ✓ HC-SCR promising for small passenger cars & small tempo type vehicles
- ✓ Unburnt HC or little fuel penalty needed compared to noble metal cost in LNT & catalyst replacement
- ✓ Alumina as support hence present alumina wash-coated monoliths can be good starting point
- ✓ No ready-made technology available but promising lab scale results available

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Thank You